2006 NYS IPM Agricultural Grants Program – Progress Report

Project Type: Research and Development

Title: Agronomics and Economics of potato leafhopper (PLH)-resistant alfalfa intercropped with perennial forage grass for PLH control

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Abstract: Potato leafhopper (PLH) is the most damaging alfalfa pest in the Northeast (NE). Forage grasses mixed with alfalfa can cause PLH to emigrate but may reduce forage quality. Some alfalfa cultivars have PLH-resistance, yet are not immune to PLH damage. The objectives are to compare PLH populations and densities, and forage yield and quality of a conventional alfalfa cultivar and a PLH-resistant cultivar both in monoculture and intercropped with grass, to conduct an economic analysis, and to share results in extension outreach. For conventional alfalfa not sprayed with insecticide, the alfalfa : grass mixture plots compared to the monoculture alfalfa plots averaged significantly lower PLH damage scores (2.7 vs. 3.2), lower number of PLH insects in 5 sweeps (19.4 vs. 30.0), and higher total season yield (2.11 t/a vs. 1.88 t/a ($P<0.0677$)). For PLH-resistant alfalfa, planting with a grass did not significantly reduce PLH damage and populations more than was achieved by using a PLH-resistant alfalfa cultivar. Even though the PLH-resistant alfalfa cultivars stayed green when some PLH were observed, the cultivars were still significantly stunted from this feeding damage compared to alfalfa that was treated with insecticide.

Background and Justification:
It is estimated that two-thirds of the alfalfa acreage in the NE include a perennial forage grass, most often timothy (*Phleum pratanse* L.) or orchardgrass (*Dactylis glomerata* L.).

Potato leafhopper (PLH) is the most widespread and damaging insect pest of alfalfa in the NE, causing risk to new seeding establishment and survival, and to established stands during mid-to-late summer. When high populations of PLH are not controlled during the establishment year, large reductions in alfalfa yield and quality can occur (Flinn and Hower 1984, Davis and Fick 1995, Hansen et al., 2002).

To minimize risk and avoid economic impacts growers are encouraged to monitor crops frequently and, when PLH populations warrant, harvest the forage early or treat with a properly labeled insecticide. Unfortunately, many insecticides currently registered for alfalfa bear the restriction “Apply only to fields planted to pure stands of alfalfa” and as such are not appropriately labeled for mixed stands of alfalfa:clover:grasses. NYS Department of

Environmental Conservation (DEC) and USEPA issued a Crisis Exemption for the use of the insecticide Warrior to control PLH in mixed alfalfa:grass stands in 2002-2005. This exemption, however, was not granted in 2006 leaving New York producers of alfalfa:grass mixtures without an insecticide control option at this time.

In years of severe PLH infestations, early forage harvest alone will not adequately control insect populations. The establishment year is when PLH populations can cause the most damage (Flinn and Hower, 1984). Frequent early harvest and excessive PLH injury in the establishment year of spring seedings can weaken alfalfa making the field susceptible to winter injury and disease. In addition to early harvest, other non-pesticide PLH management techniques include the use of PLH-resistant alfalfa cultivars and planting perennial grass as a companion crop to the alfalfa.

Potato leafhopper-resistant alfalfa cultivars first became commercially available in 1997 and offer producers a degree of relief from PLH damage. Alfalfa breeders successfully incorporated glandular-hairs from perennial wild-type tetraploid and diploid Medicago species with resistance to PLH into modern alfalfa germplasm (McCaslin, 1994). Hansen et al. (2002) have shown that early generation PLH-resistant alfalfa cultivars, while not immune to PLH, had reduced PLH damage symptoms, were superior in feed quality than many of the conventional alfalfa cultivars tested, and were well adapted to NY growing conditions. Similar results were found in caged alfalfa experiments in Iowa (Lefko et al, 2000) and in field trials conducted in Ohio, Indiana, Wisconsin, and Minnesota (Sulc, et al, 2001).

Current seed costs of PLH-resistant cultivars are comparable to conventional alfalfa cultivars and a limited number of new PLH-resistant cultivars are available to producers. The new PLH-resistant cultivars have more than 75% resistance to PLH insects (Peterson, 2003). Recent studies by Sulc et al. (2004) suggest an alfalfa cultivar with high resistance to PLH may have an economic threshold for damage by PLH that is three to four times higher than the threshold for a conventional, non-glandular haired cultivar. From PLH sweep data, Hansen, et al. (2002) found that planting a PLH-resistant alfalfa cultivar reduced PLH numbers by an average of 47% compared to planting a conventional alfalfa cultivar. This reduction was greater in the production years than in the establishment year. Potato leafhopper resistant alfalfa cultivars may likely need to be sprayed with insecticide in the seeding year when PLH populations do the most damage, and perhaps at other times during the life of the stand when PLH populations are at particularly damaging levels.

Other researchers have found that intercropping alfalfa with grasses can reduce PLH populations. In mixtures of conventional alfalfa with either smooth bromegrass or orchardgrass, PLH populations were reduced compared to alfalfa monocultures, but not below economic thresholds (DeGooyer et al., 1999). From this same study, it was estimated that PLH numbers per alfalfa stem were not significantly lower for the alfalfa : grass intercrops than for the alfalfa monoculture. Davis and Fick (1995) reported PLH nymph populations on a per stem basis were not affected by timothy alfalfa mixtures. On a per area basis, however, nymph densities were higher in alfalfa monocultures than in alfalfa timothy mixtures. Research reported by Roda et al. (1997a), found that numbers of adult PLH were reduced by 22-48% in alfalfa : grass mixtures of either smooth bromegrass or orchardgrass. Smooth bromegrass and orchardgrass intercropped with alfalfa, planted at high densities, ca. 78% alfalfa and 22% grass, consistently had lower

numbers of adult PLH than alfalfa alone. Mixtures of alfalfa with timothy showed both increases and decreases in PLH populations compared to alfalfa alone. The authors hypothesized that overall lower percentages of timothy (7%) in the stand compared with bromegrass and orchardgrass may have contributed to this variability. Also, as alfalfa biomass in the mixture increased, leafhopper emigration decreased. Further research showed that PLH emigration resulted from physical contact with grass rather than from grass volatiles (Roda et al., 1997b). Also, monocotyledonous plants such as grasses and sedges do not sustain the development of PLH nymphs (Lamp et al., 1994). Intercropping forage grass with alfalfa could reduce PLH numbers at harvest by up to 48% (Roda, et al, 1997a).

Research data regarding potential effects of PLH on PLH-resistant alfalfa cultivars combined with a perennial forage grass species are extremely limited. Potato leafhopper populations, PLH damage to the alfalfa, yield, and forage quality were measured on PLH-resistant alfalfa planted with and without timothy (Waldron, et al, 2004). The alfalfa : grass mixture averaged 10% alfalfa, a significantly lower percentage of alfalfa in the mixture than reported in studies by Davis and Fick (1995) and by Roda (1997a). The PLH-resistant cultivar had 36% fewer PLH than the susceptible cultivar; however, the number of PLH was significantly higher than for the plots that were sprayed with insecticide (average less than 1 PLH per sub-plot). The combination of the PLH- resistant cultivar and timothy resulted in significantly better PLH control than did the resistant cultivar alone. For the plots that were not sprayed with insecticide, the plot with the lowest PLH damage was the resistant alfalfa/grass mixture (score = 1.8; score 1=no damage to 5=severe damage), whereas the resistant cultivar alone scored 2.4 and the susceptible cultivar alone and with grass averaged 3.5. This study was not continued past the seeding year due to winter injury.

The following study is designed to conduct a detailed agronomic and economic analysis of the effect of PLH-resistant alfalfa intercropped with one of three perennial forage grasses: timothy, orchardgrass, or tall fescue (*Festuca arundinacea* Schreb) on PLH populations, crop damage, and indications of profitability. Much of the gain in improved PLH control by intercropping grass with PLH-resistant alfalfa is expected to be in the establishment year since at this time the PLH-resistant alfalfa still sustains significant risk of injury when PLH populations are high.

Procedure:
A field plot trial was planted at the Cornell University - NYSAES Horticulture Research Farm in Geneva New York May 8, 2006. The Geneva soil type is a Honeoye fine sandy loam.

The trial design is a split-plot with insecticide treatment as the main plot, and alfalfa and alfalfa-grass mixtures as the sub-plots. Six main plots were planted. One-half of each main plot was sprayed with insecticide to minimize damage from PLH and one-half was not sprayed. Alleyways between the main plots will be large enough to avoid drift of the pesticide when spraying. Timing of insecticide treatments was based on need determined by weekly plot PLH monitoring.

The sub-plots were planted with either WL 347LH, an alfalfa cultivar with high resistance to PLH, or WL 357HQ, a conventional (*PLH susceptible*) alfalfa cultivar. Subplots were either clear-seeded or planted in combination with “Summit” timothy, “Intensiv” Orchardgrass, or

"Enhance" Tall Fescue. The grass varieties were chosen based on similar date of spring flowering or heading. Each main plot contains eight treatments.

Plots were seeded with a 6-row Carter seeder that seeded plots that are 3.5 feet wide and 20 feet long. Each plot was seeded twice, first with alfalfa and then with either alfalfa or grass, for a within plot row spacing of 3 inches and an overall size of 4 x 16 feet. Three plots of each treatment were planted side by side. All data were collected on the middle plot. Seeding rates were 20 lb/A alfalfa alone and 12 lb/A alfalfa plus 6, 7, or 10 lb/A timothy, orchardgrass, or tall fescue, respectively. Plots were treated with Butyrac (1 qt/A) for weed control on 15-Jun-06.

Main plots were monitored weekly for PLH populations (21-Jun, 28-Jun, 5-Jul, 14-Jul, 20-Jul, 26-Jul, 16-Aug, 31-Aug, 6-Sep) using standard NYS alfalfa IPM practices (10 sweeps per plot). Insecticide plots were sprayed with 'Warrior' insecticide (0.2 pt/A, Zeneca Ag Products, Wilmington, DE) on 06-Jul-06 and 23-Aug-06.

Plots were harvested August 2 and September 22. The day before Harvest 1 (August 2) , each plot was swept five times with a standard 15 inch diameter sweep net, and the PLH adults and nymphs were counted. For nymph counts on only the alfalfa portion of the plot, ten alfalfa stems were cut from within each plot area, carefully placed in a plastic bag (one bag per plot), and placed in a cooler for counting the day after collection. Samples of each plot were hand-harvested at 5 cm cutting height. The alfalfa, grass, and weeds were separated, placed in separate paper bags, and dried at 55 degrees C. These bag weights were used to calculate %alfalfa, %grass, and % weeds for each plot, and the alfalfa and grass portions of the plots were combined for use in forage quality analyses. The height of alfalfa stems and grass canopy was measured for each plot. The alfalfa portion of the sample was rated for PLH damage on a scale of one to five where one is a sample that has no apparent or minor PLH damage and a five is a sample with severe stunting and yellowing symptoms of PLH damage (McCaslin and Miller, 1998). Following hand harvest and data collection, the plots were mechanically harvested for yield. Samples for dry matter correction were taken from every plot at harvest time. At Harvest 2 (September 22) when the PLH populations were very low, the following data were collected: hand-harvested samples for forage quality analyses, visual estimation of percent alfalfa and percent grass, alfalfa and grass height, PLH damage score, and yield.

All samples have been collected and are being processed. Forage samples have been dried, and percent grass and alfalfa per plot determined. These samples will be recombined and used to determine forage quality. Grinding of dried samples is still in progress so forage quality analysis has not been completed at this time. Forage quality will be predicted by NIRS. Approximately twenty percent of the samples collected will be analyzed in a wet-chemistry lab for concentrations of crude protein, neutral detergent fiber, and neutral detergent fiber digestibility. These data will be used to develop calibration equations that will be applied to the whole data set for prediction of forage quality components.

Although yield and field data are available now, a more complete partial budget economic analysis will be developed when forage quality (milk per acre) information is available. Retail seed prices on a cost per pound basis were $3.90 for WL 347LH and for WL 357HQ, $1.36 for "Summit" timothy, $2.25 for "Intensiv" orchardgrass, and $1.54 for "Enhance" tall fescue.

Insecticide cost (Warrior) if applied by a commercial applicator is estimated at $4/acre with application costs at $9/acre, for a total of $13/acre.

The data were analyzed as a split-plot by SAS Proc Mixed. Contrasts of interest were estimated and tested for statistical significance.

Results and Discussion:
The alfalfa : grass mixture trial planted at Geneva established well in spite of record high precipitation during the growing season. Initial field conditions at the Geneva site were, unfortunately, not perfect for a forage seeding. Primary tillage by moldboard plow left the soil cloddy and rough. Multiple secondary chisel plow and rotovator tillage operations were required to produce an adequate seed bed.

Weeds were generally controlled with Butyrac except for buckwheat which was hand-weeded out of the plot areas on June 29. On August 2, the percent weeds averaged 9.9% of the plot dry matter over all treatments (Table 1). The grass portion of the alfalfa : grass mixture plots averaged 13.3% of the plot dry matter. The percent grass in the alfalfa : orchardgrass plots averaged 15.3%, in the alfalfa : timothy plots averaged 13.0%, and in the alfalfa : tall fescue plots averaged 11.7%. Establishment conditions favored the alfalfa portion of the alfalfa : grass mixtures plots at Geneva.

At Harvest 2 on September 22, the percent grass for the alfalfa : grass mixtures plots averaged 32.7% (Table 1). The percent grass in the alfalfa : orchardgrass plots averaged 43.2%, in the alfalfa : timothy plots averaged 26.1%, and in the alfalfa : tall fescue plots averaged 28.8%.

Main plots were monitored weekly for PLH populations using standard NYS alfalfa IPM practices (10 sweeps per plot) (Table 2). Potato leafhopper (PLH) populations in main plots remained low to moderate throughout the summer months. PLH adult numbers peaked the week of July 20, while PLH nymph counts peaked a week later at the July 24 sampling. PLH populations virtually disappeared by the end of August. As expected, non-insecticide or untreated plots had a higher PLH population with numbers approaching, but never exceeded action threshold guidelines (Figure 1). The yellowing symptoms indicative of PLH injury were evident on alfalfa in non-insecticide treated plots at Harvest 1. Insecticide treatments clearly reduced PLH numbers collected per plot.

<u>Yield, Grass Canopy Height at Harvest 1, and Alfalfa Height at Harvest 2</u>
The insecticide treatment by entry interaction was not significant for yield and grass canopy height at Harvest 1, and alfalfa height at Harvest 2. For these traits measured, data average over spray treatments will be discussed.

The insecticide treated plots averaged 2.31 tons per acre dry matter compared to 2.10 tons per acre for untreated plots ($p<0.0576$, Table 3). Averaged over all treatments, the yield of PLH-resistant alfalfa was not significantly different from conventional alfalfa, and the yield of the alfalfa : grass plots was not significantly greater than the alfalfa alone plots except at Harvest 2 where the alfalfa : grass plots averaged 0.09 tons per acre more that the alfalfa alone plots ($P<00001$). Comparing insecticide treated and untreated plots, the lowest yielding plot was the

conventional alfalfa monoculture (2.05 t/a) and the highest yielding plot was the PLH-resistant alfalfa monoculture (2.30 t/a). The alfalfa : grass mixtures plots ranged in yield from 2.18 to 2.26 t/a.

The grass canopy at Harvest 1 was taller in the untreated plots than the treated plots (P<0.0194*, Table 4), indicating that the grass was more competitive with the alfalfa when the alfalfa was damaged from PLH feeding. The orchardgrass in the alfalfa : grass mixtures plots averaged 26.8 cm, tall fescue averaged 24.0 cm, and timothy averaged 21.2 cm. Alfalfa height at Harvest 2 averaged 37.6 cm and comparisons tested were not statistically significant.

PLH Damage / Populations, Alfalfa Height at Harvest 1, and Grass Canopy Height at Harvest 2

The insecticide treatment by entry interaction was significant for all measures related to damage by PLH at Harvest 1, for alfalfa height at Harvest 1, and for grass canopy height at Harvest 2, so significant differences in data measures are discussed for the insecticide treated and the untreated plots separately.

Insecticide Treated Plots

The insecticide treated plots showed no visible sign of PLH feeding damage (Table 5). Just prior to Harvest 1, the number of PLH insects (adult PLH + nymphs) per five sweeps averaged 3.8. All comparisons tested were not statistically significant.

The height of the alfalfa averaged over all insecticide treated plots at Harvest 1 was 58.4 cm (Table 6) and the height of the grass canopy averaged over the insecticide treated alfalfa : grass mixture plots at Harvest 2 was 32.2 cm. The alfalfa at Harvest 1 was significantly taller in the alfalfa monoculture plots (66.5 cm) compared to the alfalfa in the alfalfa : grass mixture plots (55.7 cm) (P<0.0005, Table 6). The grass canopy at Harvest 2 was taller in the conventional alfalfa plots (25.9 cm) compared to the PLH-resistant alfalfa plots (22.5 cm) (P<0.0016).

No Insecticide or Untreated Plots

At Harvest 1 the average PLH damage score for the conventional alfalfa plots was 2.8 and for the PLH-resistant alfalfa plots was 1.6 (P<0.0001, Table 7). The PLH damage score for the alfalfa : grass mixtures plots (2.1) was not significantly lower than for the average alfalfa monoculture plots (2.4), but was significantly lower than the conventional alfalfa monoculture plot (3.2) (Table 7). Averaged over all untreated plots, the number of nymphs per 5 sweeps was 11.1 and the number of adult PLH insects was 6.7. The lowest number of PLH insects was in the PLH-resistant alfalfa : orchardgrass plot (12.0 insects per 5 sweeps). All of the alfalfa : grass mixtures plots had lower numbers of PLH insects (16.2 insects per 5 sweeps) compared to the conventional alfalfa monoculture plots (30.0 insects per 5 sweeps).

The number of nymphs per ten stems hand cut from each plot averaged only 1.1 and treatment differences were close to zero (Table 5). Thus, it was not possible to assess the nymph population size on just the alfalfa portion of the alfalfa : grass mixture plots in this study. Although counting the nymphs on ten stems per plot has been shown to be an adequate sample size for comparing PLH-resistant alfalfa monoculture plots with conventional alfalfa monoculture plots in the seeding year, it may have been too small of a sample size for this study under low PLH pressure.

The PLH-resistant alfalfa averaged 5 cm taller than the conventional alfalfa in plots not treated with an insecticide ($P<0.0018$, Table 8). However, the PLH-resistant alfalfa in the untreated plots was significantly shorter (45.0 cm, Table 8) than average alfalfa in the treated plots (58.7 cm, Table 6).

Alfalfa : Grass Mixtures vs Alfalfa Monoculture

A summary of treatment effects for alfalfa : grass mixtures vs alfalfa monoculture is presented in Table 9. For conventional alfalfa, the alfalfa : grass mixture plots compared to the monoculture alfalfa plots averaged significantly lower PLH damage scores (2.7 vs. 3.2), lower number of PLH insects in 5 sweeps (19.4 vs. 30.0), and higher total season yield (2.11 t/a vs. 1.88 t/a ($P<0.0677$)). Thus, under relatively low populations of PLH in the seeding year when PLH are not controlled with insecticides, planting a grass with conventional alfalfa was shown to reduce the numbers of PLH insects, reduce PLH damage to the alfalfa, and increase yield. Concerns about reduced forage quality of alfalfa : grass mixtures compared to alfalfa monoculture will be addressed once work in the forage quality laboratory is complete.

For PLH-resistant alfalfa, the alfalfa : grass mixture plots compared to the monoculture alfalfa plots were not significantly different for insect damage or yield. Thus, planting a grass with PLH-resistant cultivars may be recommended for agronomic reasons, but did not reduce PLH damage and populations even further than was achieved by using a PLH-resistant alfalfa cultivar alone.

Data from this study suggests that even though PLH-resistant alfalfa cultivars are a significant advancement in integrated pest management for PLH insects, maximum yields are still achieved through complete control of PLH by insecticide applications. Differences in seed, insecticide and other input costs are not expected to be significant, however , effects on yield and quality could be. Results from a planned, but not yet available, forage quality analysis and a partial budget evaluation are expected to add to this discussion. The PLH-resistant alfalfa cultivar stayed green when a few PLH were feeding, however, this variety was still significantly stunted from this amount of feeding damage as shown by alfalfa height measurements. Through plant breeding, it may be possible to select specifically for PLH-resistant plants that are not stunted by PLH feeding.

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Project location(s):

Cornell University - NYSAES Horticulture Research Farm in Geneva, New York.
Research findings applicable to northeastern US and other regions with similar alfalfa : grass production systems.

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Figure 1. Potato leafhopper adult and nymph populations in insecticide-treated and untreated main treatment field plots in Geneva, NY 2006.

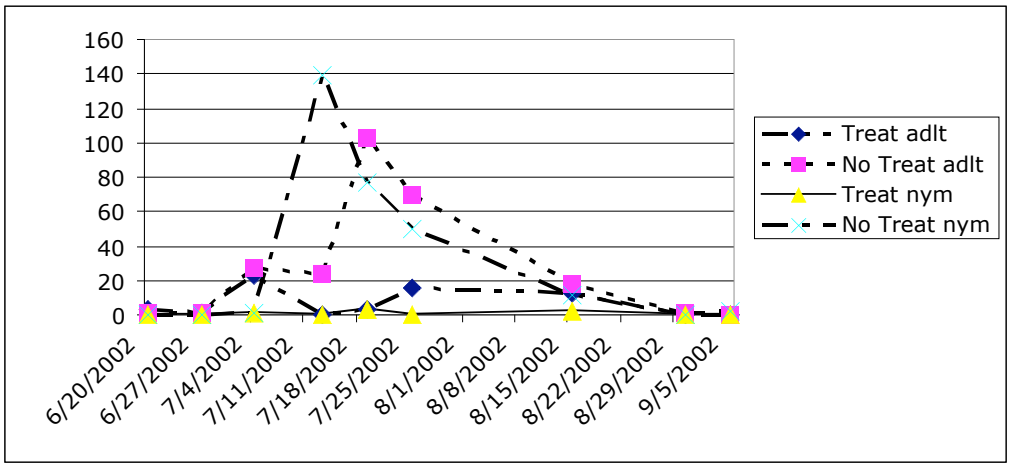

Table 1. Botanical composition of alfalfa and alfalfa : grass mixture plots in Geneva NY new seedings 2006. Insecticide treatment by subplot interaction was not significant so data are averaged over insecticide treatment.

Planned Comparisons:	%Alfalfa 2-Aug	%Grass 2-Aug	%Weeds 2-Aug	%Alfalfa 22-Sep	%Grass 22-Sep
Avg. Treated	81.05	9.98	9.00	78.53	21.65
Avg. Untreated	77.80	11.45	10.85	72.75	27.38
p-value (trt)	0.3030 ns	0.1982 ns	0.4683 ns	0.1536 ns	0.1547 ns
Avg. Res. Alfalfa	79.88	10.65	9.68	75.75	24.38
Avg. Con. Alfalfa	78.98	10.78	10.18	75.53	24.65
p-value (trt)	0.6002 ns	0.9126 ns	0.6979 ns	0.8954 ns	0.8724 ns
Avg. Alf. + Grass	76.13	13.30	10.63	67.52	32.68
Avg. Alfalfa Mono.	89.30	2.95	7.80	100.00	0.00
p-value (trt)	0.0001 **	0.0001 **	0.0606 ns	0.0001 **	0.0001 **
Sub-Plot Means	%Alfalfa 2-Aug	%Grass 2-Aug	%Weeds 2-Aug	%Alfalfa 22-Sep	%Grass 22-Sep
Conv. Alfalfa Mono.	88.30	2.80	8.80	100.00	0.00
PLH-Alfalfa Mono.	90.30	3.10	6.80	100.00	0.00
Conv. Alfalfa + Orchardgr.	73.50	15.20	11.30	58.60	41.60
PLH-Alfalfa + Orchardgr.	74.50	15.30	10.30	55.30	44.80

Conv. Alfalfa + Tall Fescue	79.60	11.90	8.50	72.40	27.90
PLH-Alfalfa + Tall Fescue	79.70	11.50	9.10	70.60	29.60
Conv. Alfalfa + Timothy	74.50	13.20	12.10	71.10	29.10
PLH-Alfalfa + Timothy	75.00	12.70	12.50	77.10	23.10

Table 2. Potato leafhopper (PLH) populations in alfalfa and alfalfa : grass mixtures at NYSAES field plots summer 2006.

Insecticide Applied?	Measurement	21-Jun	28-Jun	5-Jul	14-Jul	20-Jul	26-Jul	16-Aug	31-Aug	6-Sep
Yes	PLH adult *	3	1	23	0	3	16	12	0	0
No	PLH adult *	1	1	27	24	103	70	18	1	0
Yes	PLH nymph*	0	0	1	0	3	0	2	0	0
No	PLH nymph*	0	0	1	139	77	50	11	0	2
Yes	plant height	5.3	7.8	10.5	16.0	17.3	18.3	7.5	14.5	17.3
No	plant height	6.7	8.0	10.8	14.3	16.2	18.3	7.8	14.0	17.7

* Figure is sum of PLH collected in each of six main plots (10 sweeps per plot), plant heights are averages from the six main plots.

Table 3. Yield in tons per acre dry matter of alfalfa and alfalfa : grass mixture plots in Geneva NY new seedings 2006. Insecticide treatment by subplot interaction was not significant so data are averaged over insecticide treatment.

Planned Comparisons	**Harvest 1 2-Aug**	**Harvest 2 22-Sep**	**Total Yield**
Avg. Treated	1.43	0.88	2.31
Avg. Untreated	1.27	0.82	2.10
p-value (trt)	0.0725 ns	0.1915 ns	.0576 ns
Avg. Res. Alfalfa	1.36	0.86	2.22
Avg. Con. Alfalfa	1.34	0.85	2.19
p-value (trt)	0.6668 ns	0.2543 ns	0.4717 ns
Avg. Alf. + Grass	1.34	0.88	2.22
Avg. Alfalfa Mono.	1.39	0.79	2.18
p-value (trt)	0.2597 ns	0.0001 **	0.4456 ns

Sub-Plot Means	**Harvest 1 2-Aug**	**Harvest 2 22-Sep**	**Total Yield**
Conv. Alfalfa Mono.	1.30	0.74	2.05
PLH-Alfalfa Mono.	1.47	0.83	2.30
Conv. Alfalfa + Orchardgr.	1.38	0.88	2.26
PLH-Alfalfa + Orchardgr.	1.32	0.86	2.18
Conv. Alfalfa + Tall Fescue	1.33	0.91	2.24
PLH-Alfalfa + Tall Fescue	1.29	0.90	2.19

Conv. Alfalfa + Timothy	1.35	0.85	2.20
PLH-Alfalfa + Timothy	1.35	0.86	2.22

Table 4. Alfalfa and grass canopy height of alfalfa and alfalfa : grass mixture plots in Geneva NY new seedings 2006. Insecticide treatment by subplot interaction was not significant so data are averaged over insecticide treatment.

Planned Comparisons	**Grass Canopy Height (cm) Aug-2**	**Alfalfa Height (cm) Sept-22**
Avg. Treated	17.15	38.65
Avg. Untreated	20.43	36.45
p-value (trt)	0.0194 *	0.2100 ns
Avg. Res. Alfalfa	18.15	37.28
Avg. Con. Alfalfa	19.43	37.83
p-value (trt)	0.3536 ns	0.5334 ns
Avg. Alf. + Grass	24.00	37.70
Avg. Alfalfa Mono.	3.15	37.10
p-value (trt)	0.0001**	0.5562 ns

Sub-Plot Means	**Grass Canopy Height (cm) Aug-2**	**Alfalfa Height (cm) Sept-22**
Conv. Alfalfa Mono.	6.30	36.50
PLH-Alfalfa Mono.	0.00	37.70
Conv. Alfalfa + Orchardgr.	26.70	39.70
PLH-Alfalfa + Orchardgr.	26.90	37.10
Conv. Alfalfa + Tall Fescue	25.60	37.60
PLH-Alfalfa + Tall Fescue	22.40	36.20
Conv. Alfalfa + Timothy	19.10	37.50
PLH-Alfalfa + Timothy	23.30	38.10

Table 5. Potato leafhopper (PLH) damage and populations at Harvest 1 of alfalfa and alfalfa : grass mixture plots in Geneva NY new seedings 2006. Data are for plots treated with Insecticide

Planned Comparisons – Insecticide Treated Plots

	PLH Damage Score[a] 2-Aug	Nymph No. per 10 stems 2-Aug	No. of PLH adults 2-Aug	No. of PLH Nymphs 2-Aug	Total No. of PLH 2-Aug
Avg. Res. Alfalfa	1.00	0.05	2.85	0.75	3.60
Avg. Con. Alfalfa	1.00	0.20	2.95	1.10	4.05
p-value (trt)	ns	0.6383 ns	0.6103 ns	0.5707 ns	0.9279 ns
Avg. Alf. + Grass	1.00	0.10	3.07	0.90	3.97
Avg. Alfalfa Mono.	1.00	0.20	2.40	1.00	3.40
p-value (trt)	ns	0.0650 ns	0.7682 ns	0.5558 ns	0.4990 ns

Sub-Plot Means	PLH Damage Score [a] 2-Aug	Nymph No. per 10 stems 2-Aug	No. of PLH adults 2-Aug	No. of PLH Nymphs 2-Aug	Total No. of PLH 2-Aug
Conv. Alfalfa Mono.	1.00	0.20	2.40	0.80	3.20
PLH-Alfalfa Mono.	1.00	0.40	3.20	0.60	3.80
Conv. Alfalfa + Orchardgr.	1.00	0.00	2.60	0.80	3.40
PLH-Alfalfa + Orchardgr.	1.00	0.20	2.40	1.20	3.60
Conv. Alfalfa + Tall Fescue	1.00	0.20	2.80	1.60	4.40
PLH-Alfalfa + Tall Fescue	1.00	0.00	3.20	0.60	3.80
Conv. Alfalfa + Timothy	1.00	0.00	3.40	1.00	4.40
PLH-Alfalfa + Timothy	1.00	0.00	3.20	0.80	4.00

[a] 1 is no apparent injury, 2 is very minor stunting and yellowing, 3 is moderate stunting with yellowing evident on 20 to 40% of leaves, 4 is significant stunting and yellowing on 40 to 60% of leaves, and 5 is severe stunting and yellowing on 60 to 100% of leaves.

Table 6. Alfalfa height at Harvest 1 and grass canopy height at Harvest 2 of alfalfa and alfalfa : grass mixture plots in Geneva , NY new seedings 2006. Data are for plots treated with Insecticide.

Planned Comparisons – Insecticide Treated Plots

	Alfalfa Height (cm) 2-Aug	**Grass Canopy Height (cm) Sept-22**
Avg. Res. Alfalfa	58.70	22.45
Avg. Con. Alfalfa	58.10	25.85
p-value (trt)	0.8038 ns	0.0016 **
Avg. Alf. + Grass	55.70	32.20
Avg. Alfalfa Mono.	66.50	0.00
p-value (trt)	0.0005 **	0.0001 **

Sub-Plot Means	**Alfalfa Height (cm) 2-Aug**	**Grass Canopy Height (cm) Sept-22**
Conv. Alfalfa Mono.	67.00	0.00
PLH-Alfalfa Mono.	66.00	0.00
Conv. Alfalfa + Orchardgr.	53.00	36.20
PLH-Alfalfa + Orchardgr.	54.00	34.80
Conv. Alfalfa + Tall Fescue	55.00	33.60
PLH-Alfalfa + Tall Fescue	58.40	31.00
Conv. Alfalfa + Timothy	57.40	33.60
PLH-Alfalfa + Timothy	56.40	24.00

Table 7. Potato leafhopper (PLH) damage and populations at Harvest 1 of alfalfa and alfalfa : grass mixture plots in Geneva NY new seedings 2006. Data are for plots not treated with Insecticide

Planned Comparisons –Untreated Plots

	PLH Damage Score[a]	**Nymph No. per 10 stems**	**No. of PLH adults**	**No. of PLH Nymphs**	**Total No. of PLH**
	2-Aug	**2-Aug**	**2-Aug**	**2-Aug**	**2-Aug**
Avg. Res. Alfalfa	1.58	1.20	5.80	7.80	13.60
Avg. Sus. Alfalfa	2.78	1.00	7.60	14.45	22.05
p-value (trt)	0.0001 **	0.7334 ns	0.0298 **	0.0002 **	0.0001 **
Avg. Alfalfa + Grass	2.11	1.10	6.13	10.03	16.17
Avg. Alfalfa alone	2.36	1.10	8.40	14.40	22.80
p-value (trt)	0.1898 ns	ns	0.0187 **	0.0215 *	0.0032 **

Sub-Plot Means	**PLH Damage Score [a]** **2-Aug**	**Nymph No. per 10 stems** **2-Aug**	**No. of PLH adults** **2-Aug**	**No. of PLH Nymphs** **2-Aug**	**Total No. of PLH** **2-Aug**
Conv. Alfalfa Mono.	3.16	1.00	10.20	19.80	30.00
PLH-Alfalfa Mono.	1.56	1.20	6.60	9.00	15.60
Conv. Alfalfa + Orchardgr.	2.52	0.80	6.60	10.40	17.00
PLH-Alfalfa + Orchardgr.	1.72	2.20	4.60	7.40	12.00
Conv. Alfalfa + Tall Fescue	2.72	1.00	6.60	15.60	22.20
PLH-Alfalfa + Tall Fescue	1.26	1.00	4.80	8.40	13.20
Conv. Alfalfa + Timothy	2.70	1.20	7.00	12.00	19.00
PLH-Alfalfa + Timothy	1.76	0.40	7.20	6.40	13.60

[a] 1 is no apparent injury, 2 is very minor stunting and yellowing, 3 is moderate stunting with yellowing evident on 20 to 40% of leaves, 4 is significant stunting and yellowing on 40 to 60% of leaves, and 5 is severe stunting and yellowing on 60 to 100% of leaves.

Table 8. Alfalfa height at Harvest 1 and grass canopy height at Harvest 2 of alfalfa and alfalfa : grass mixture plots in Geneva , NY new seedings 2006. Data are for plots not treated with Insecticide

Planned Comparisons –Untreated Plots

	Alfalfa Height (cm)	**Grass Canopy Height (cm)**
	2-Aug	**Sept-22**
Avg. Res. Alfalfa	45.00	25.90
Avg. Sus. Alfalfa	40.40	24.60
p-value (trt)	0.0018 **	0.2648 ns
Avg. Alfalfa + Grass	42.57	33.67
Avg. Alfalfa alone	43.10	0.00
p-value (trt)	0.7321 ns	0.0001 **

Sub-Plot Means	**Alfalfa Height (cm) 2-Aug**	**Grass Canopy Height (cm) Sept-22**
Conv. Alfalfa Mono.	39.20	0.00
PLH-Alfalfa Mono.	47.00	0.00
Conv. Alfalfa + Orchardgr.	43.80	35.00
PLH-Alfalfa + Orchardgr.	44.80	35.60
Conv. Alfalfa + Tall Fescue	39.80	32.40
PLH-Alfalfa + Tall Fescue	43.20	34.00
Conv. Alfalfa + Timothy	38.80	31.00
PLH-Alfalfa + Timothy	45.00	34.00

Table 9: For the plots not treated with insecticide, planned comparisons between alfalfa monoculture and alfalfa : grass mix plots for the conventional alfalfa cultivar and PLH-resistant alfalfa cultivar for PLH damage score, number of PLH insects, and yield.

Comparison	Alfalfa Variety	Alfalfa Monoculture	Alfalfa :Grass Mix	Difference	P-value	Significance
PLH Damage Score*	Conventional	3.2	2.7	0.5	0.0579	*
	PLH Resistant	1.6	1.6	0.0	0.9391	ns
# PLH Adults	Conventional	10.2	6.7	3.5	0.0116	**
	PLH Resistant	6.6	5.5	1.1	0.4131	ns
# PLH Nymphs	Conventional	19.8	12.7	7.1	0.0089	**
	PLH Resistant	9.0	7.4	1.6	0.5331	ns
# PLH Total	Conventional	30.0	19.4	10.6	0.0011	**
	PLH Resistant	15.6	12.9	2.7	0.3663	ns
Yield - Harvest 1	Conventional	1.18	1.28	-0.10	0.3564	ns
	PLH Resistant	1.42	1.25	0.17	0.0807	ns
Yield - Harvest 2	Conventional	0.70	0.84	-0.14	0.0015	**
	PLH Resistant	0.80	0.86	-0.06	0.2118	ns
Yield Total Season	Conventional	1.88	2.11	-0.23	0.0677	ns
	PLH Resistant	2.23	2.11	0.12	0.3357	ns

*PLH damage score: 1 is not apparent damage to 5 is severe damage, Average number PLH per 5 sweeps/plot, 6 replications, Yield in tons per acre dry matter.